

Claims 13, 14, 25 and their dependent claims

The Office Action asserts that the sole difference between Tamatsuka and independent claims 13, 14, 25 and their dependent claims is the F/G value. Applicants disagree with this characterization.

First, Applicants respectfully point out that the asserted F/G value referenced by the Office Action is not included in any of the pending independent claims. Rather, the F/G value appears only in dependent claims 26 and 27. The Office Action thus fails to allege how the claimed invention of at least the independent claims would have been obvious over the cited references. For all of the reasons set forth below, the claimed invention would not have been obvious over the cited references, at least based on the limitations of the independent claims.

Tamatsuka describes the silicon single crystal wafer as doped with nitrogen and having an epitaxial layer formed in the surface layer portion of the silicon single crystal wafer. See Tamatsuka, claim 1. Tamatsuka does not relate to, and does not teach or suggest, a wafer having an N-region for the entire plane, as set forth in claims 13 and 25. In addition, Tamatsuka neither discloses nor suggests the oxygen concentration range of claims 13, 14 and 25. Since Tamatsuka does not define the oxygen concentration as specifically being 8 ppma or less, an OSF ring generated by nitrogen doping can not be inactivated. See Specification, page 19, lines 19-26.

Tamatsuka describes that an epitaxial layer is formed in the surface layer portion of a silicon single crystal wafer that is doped with nitrogen. Unlike claims 13 and 25, Tamatsuka does not relate to a wafer having an N-region for the entire plane. Tamatsuka does not teach or suggest such a limitation, and thus cannot have rendered obvious this feature of the claims.

The Office Action asserts that the nitrogen doping in Tamatsuka would inherently produce an N-region across the entire wafer as claimed. Contrary to this unsupported

assertion, a silicon single crystal doped with nitrogen will not automatically produce a crystal having an N-region for the entire plane. Doping with nitrogen will enlarge the N-region of a crystal, but will not necessarily produce an N-region across the entire plane. See Specification, page 6, lines 14-19; page 10, line 27 to page 11, line 10. A crystal having an N-region for the entire plane will not be obtained unless the crystal is pulled under a condition such that the entire plane will become an N-region, even if the crystal is doped with nitrogen. That is, a crystal having an N-region for the entire plane will be obtained only if the crystal is pulled, doped with nitrogen, controlling an F/G value to a predetermined value. Mere doping of a crystal with nitrogen will not inherently, in all instances, result in an N-region over the entire plane, as claimed.

Furthermore, although Tamatsuka discloses nitrogen doping, controlling an F/G value is not disclosed or suggested in the reference. Tamatsuka does not disclose, teach or suggest pulling a crystal under the conditions to produce an N-region across the entire plane. The example of Tamatsuka makes clear that Tamatsuka discloses a crystal pulled at a pulling rate of 1.0 millimeters per minute or 1.8 millimeters per minute. An F/G value, a ratio of the pulling rate F and the temperature gradient G, is not disclosed or controlled. Nor does Tamatsuka teach or suggest any reason for controlling the F/G value, or that different results could or would be obtained. In addition, the pulling rate disclosed in Tamatsuka is much faster than the pulling rates disclosed in the examples of this application, which fall in the range of 0.49 through 0.77 millimeters per minute. The higher speed of Tamatsuka in fact results in the lack of formation of an N-region, rather than an N-region over the entire plane as required in the claimed invention.

Furthermore, the oxygen concentration disclosed in Tamatsuka is 18 ppma or less. This oxygen concentration range is very broad, and is not defined as the specific, extremely low oxygen concentration of 5-8 ppma as in claims 13, 14 and 25. In particular, the

Examples of Tamatsuka describe oxygen concentrations of 16 ppma (Example 1), 10.5-17.5 ppma (Example 2), 10-18 ppma (Example 3), and 16 ppma (Example 4), all well above the range claimed in claims 13, 14 and 25. Nowhere does Tamatsuka disclose, teach or suggest having the oxygen concentration in the specific, narrower range of claims 13, 14 and 25.

Tamatsuka does not disclose, teach or suggest that any benefits could be obtained by lowering the oxygen concentration to within the claimed range, rather than using an oxygen concentration of 10-18 ppma as disclosed by the Examples of Tamatsuka. Since Tamatsuka teaches, practically, an oxygen concentration of 10-18 ppma, OSF rings, generated by nitrogen doping in the silicon wafers, cannot be inactivated. In contrast, in the silicon wafers of claims 13, 14 and 25, which have a lower, defined oxygen concentration range, OSF rings generated by nitrogen doping can be inactivated.

The fact that Tamatsuka practically discloses only oxygen concentrations between 10 and 18 ppma is important because Applicants discovered that OSFs and dislocation loops are not generated in an oxygen concentration of 8 ppma or less, but are produced in oxygen concentrations of 10 ppma or more. See Specification, page 8, lines 3-10; page 19, lines 9-21. Tamatsuka does not teach or suggest that such different results would be obtained if the oxygen concentration is lowered, or that such different products would still be suitable for Tamatsuka's purposes.

In addition, if the oxygen concentration is 5 ppma or less, the crystal is completely free from not only OSFs and dislocation loops, but also from various defects. See Specification, page 8, line 2 - page 9, line 4; page 22, lines 3-7. This criticality is affirmed and demonstrated in the examples in the present application. Example 1 describes a crystal pulled under the conditions in which oxygen concentration is 4 ppma and an N-region is obtained, so that neither grown-in defects nor OSFs are observed. Likewise, in Example 2, a crystal was pulled under an oxygen concentration of 7 ppma and an N-region was obtained,

such that micro defects originated in the oxygen precipitation were observed and the wafer had high gettering ability.

In order to define the oxygen concentration range as in claims 13, 14 and 25, it is necessary to recognize that OSFs are not generated by utilizing an OSF region expanded by nitrogen doping while the oxygen concentration is 5-8 ppma, and a defect-free wafer can be made from a crystal containing no dislocation loops originating from OSF nuclei. See Specification, page 19, lines 9-21. In contrast to the assertion of the Office Action, Tamatsuka does not teach or suggest OSFs are not generated in the grown silicon crystal. At column 3, lines 10-25, Tamatsuka explains that by subjecting the wafer to the heat treatment, nitrogen or oxygen in the surface layer of the wafer can be out-diffused, and the crystal defects can be decreased. That is, it discloses the formation of a denuded zone, not the existence or absence of OSFs. Further, the next paragraph of Tamatsuka and column 8, lines 50-61 of Tamatsuka disclose that when a heat treatment is performed in an atmosphere of hydrogen gas and inert gas, OSFs are not generated because OSFs are an oxidation induced stacking fault; however, when a heat treatment is performed in an oxygen atmosphere, OSFs may be generated. In contrast, the instant application discloses prevention of OSF generation by controlling the oxygen concentration to be 8 ppma or less, which is never described in Tamatsuka.

Moreover, since fine oxide precipitates exist in the claimed silicon wafer, the wafer has IG ability. See Specification, page 20, lines 14-20. That is, since a silicon single crystal wafer that is doped with nitrogen, has an N-region for the entire plane and an interstitial oxygen concentration of 5-8 ppma is used, a silicon single crystal wafer that is defect-free and has appropriate gettering ability (i.e., a defect-free wafer with IG ability) can be provided.

The instant application recognizes and teaches the use of a specific, narrower range of oxygen concentration, a range not taught or suggested by the cited references. Claims 13, 14

and 25 recognize that OSFs are not generated by utilizing an OSF region expanded by nitrogen doping while the oxygen concentration is 5-8 ppma, and that a defect-free wafer can be made from a silicon single crystal that contains no dislocation loops originating from OSF nuclei. See Specification, page 8, lines 3-10; page 19, lines 9-21. Since fine oxide precipitates exist in the silicon wafer, the wafer has IG ability. As a result, the silicon single crystal wafer, doped with nitrogen, has an N-region for the entire plane and an interstitial oxygen concentration of 5-8 ppma. Thus, a silicon single crystal wafer that is defect-free and has appropriate gettering ability (IG ability) can be obtained.

Tamatsuka, therefore, does not teach or suggest the subject matter set forth in claims 13, 14 and 25 or their dependent claims. Combining Tamatsuka with Iida does not cure the defects of Tamatsuka.

Iida discloses a silicon wafer that is doped with nitrogen and has an N-region for the entire plane. However, the silicon wafer disclosed in Iida does not have an interstitial oxygen concentration of 5-8 ppma. Unlike claims 13, 14 and 25, Iida can not obtain a defect-free wafer with IG ability.

In particular, Iida discloses a silicon wafer that is doped with nitrogen, has an N-region for the entire plane and an interstitial oxygen concentration of 6.4-4.8 ppma. However the oxygen concentration of Iida is represented by ASTM '79 as described on page 500 of Iida. The oxygen concentration defined in the claimed invention is represented by JEIDA as described at, for example, page 19, lines 9-11. The relation between JEIDA and ASTM is $JEIDA \times 1.6 \approx ASTM '79$. See Shimura, Semiconductor Silicon Crystal Technology, p. 233 (attached). Therefore, the oxygen concentration of 6.4-4.8 ppma (ASTM '79) described in Iida is 4.0~3.0 ppma by JEIDA, which is below the concentration range specified in claims 13, 14 and 25. Thus, Iida does not disclose a wafer having the

oxygen concentration of 5-8 ppma (JEIDA) as in claims 13, 14 and 25, and does not teach or suggest increasing the oxygen concentration to be in the range of 5-8 ppma, as claimed.

Even if Tamatsuka is combined with Iida, the combination does not teach or suggest that a silicon wafer that is doped with nitrogen, has an N-region for the entire plane and the interstitial oxygen concentration of 5-8 ppma will provide a wafer that is defect-free and has IG ability. The cited references do not describe the oxygen concentration of 5-8 ppma. In fact, any combination of the references would provide a wafer having an oxygen concentration either well above the claimed range, consistent with the examples of Tamatsuka, or well below the claimed range, consistent with the requirements of Iida. Moreover, neither cited reference teaches or suggests attempting to obtain a defect-free wafer that has IG ability.

Accordingly, one of ordinary skill in the art would not have derived the subject matter of independent claims 13, 14 and 25, or likewise their dependent claims, from the combination of the cited references.

Claims 15, 16 and their dependent claims

Similarly, the Office Action asserts that the sole difference between Tamatsuka and independent claims 15, 16 and their dependent claims is the F/G. Applicants disagree with this characterization.

First, as described above, Applicants respectfully point out that the asserted F/G value referenced by the Office Action is not included in any of the pending independent claims, including independent claims 15 and 16. Rather, the F/G value appears only in dependent claims 26 and 27, which ultimately depend from independent claim 25. The Office Action thus fails to allege how the claimed invention of at least independent claims 15 and 16 would have been obvious over the cited references. For all of the reasons set forth below, the

claimed invention would not have been obvious over the cited references, at least based on the limitations of the independent claims.

In order to define the oxygen concentration range as in claims 15 and 16, it is necessary to recognize that when an oxygen concentration of 5 ppma or less is used, the wafer shows extremely good defect and electric characteristics. See Specification, page 8, line 24 - page 9, line 4; page 22, lines 3-7. But because it does not contain bulk defects, it lacks gettering ability (IG ability). See Specification, page 22, lines 7-8. Therefore, an EG treatment may be performed to impart gettering ability. See Specification, page 22, lines 9-12.

A silicon single crystal wafer that simultaneously is defect-free and possesses gettering ability (EG ability) can be obtained by the silicon single crystal wafer that is doped with nitrogen, has an N-region for the entire plane and an interstitial oxygen concentration of 5 ppma or less, and is subjected to an EG treatment. Such a wafer is disclosed for the first time in this application and is not disclosed, taught or suggested by Tamatsuka.

For at least these reasons and the reasons discussed above with respect to claims 13, 14 and 25, Tamatsuka does not teach or suggest the subject matter of independent claims 15 and 16. Tamatsuka does not teach or suggest limiting the oxygen concentration to 5 ppma or less, as recited in claims 15 and 16. Nor does Tamatsuka teach or suggest that the N-region should be for the entire plane, as claimed. Combining Tamatsuka with Iida does not cure the defects of Tamatsuka.

Iida discloses a silicon wafer that is doped with nitrogen and has an N-region for the entire plane. But unlike claims 15 and 16, Iida can not obtain a defect-free wafer with either IG ability or EG ability.

As discussed above, Iida discloses a silicon wafer which is doped with nitrogen, has an N-region for the entire plane and an interstitial oxygen concentration of 6.4-4.8 ppma by

ASTM '79 (but 4.0~3.0 ppma by JEIDA). Thus, the Iida wafer has an oxygen concentration of less than 5 ppma but is not subjected to an EG treatment. Accordingly, the Iida wafer does not have the gettering ability (EG ability) of claims 15 and 16. Iida neither describes nor suggests a defect-free wafer with gettering ability. Contrary to the assertion in the Office Action, Iida does not disclose, teach or suggest any "after treatment" to produce EG gettering ability.

Even if Tamatsuka is combined with Iida, the combination does not teach or suggest that a silicon wafer that is doped with nitrogen, has an N-region for the entire plane and the interstitial oxygen concentration of 5 ppma or less and is subjected to an EG treatment will provide a wafer that is defect-free and has EG ability. Although Iida describes an oxygen concentration of 5 ppma or less, Iida does not combine this oxygen concentration with an EG treatment and, contrary to the Office Action's assertion, no "after treatment" is disclosed. Moreover, neither cited reference teaches or suggests attempting to obtain a defect-free wafer that has EG ability. Accordingly, one of ordinary skill in the art would not have derived the subject matter of claims 15 and 16 from the combination of the cited references.

For at least these reasons, claims 15 and 16, and by the same reasoning their dependent claims, would not have been obvious over Tamatsuka in view of Iida.

Accordingly, Applicants respectfully request reconsideration and withdrawal of the rejections under 35 U.S.C. §103(a).

II. Conclusion

In view of the foregoing, it is respectfully submitted that this application is in condition for allowance. Favorable reconsideration and prompt allowance of claims 13-33 are earnestly solicited.

Should the Examiner believe that anything further would be desirable in order to place this application in even better condition for allowance, the Examiner is invited to contact the undersigned at the telephone number set forth below.

Respectfully submitted,



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